Memory Characteristics of MOS Capacitors Embedded with Ge Nanocrystals in HfO_2 Layers by Ion Implantation

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Abstract : Ge nanocrystals(NCs)-embedded MOS capacitors are characterized in this work using capacitance-voltage measurement. High-k dielectrics HfO_2 are employed for the gate material in the MOS capacitors, and the C-V curves obtained from O_2- and NH_3-annealed HfO_2 films are analyzed.

Key Words : nano-floating gate, Ge NCs, HfO_2, nitridation

1. Introduction

Nano-floating gate memory (NFGM) has attracted attention and has widely investigated for replacing conventional flash memory devices which employ continuous floating gates [1]. Si nanocrystals(NCs) usually have been investigated for NFGM and recently many studies pay attention to Ge NCs which have smaller band gap than Si NCs [2]. There has been many attempts to replace SiO_2 with higher dielectric constant materials such as HfO_2, ZrO_2, and Al_2O_3. However, in many cases high-k materials have problems with reliability and there have been many trials to improve the film stability including the annealing process [3]. In this work, HfO_2 is employed for a high-k gate material and implantation method is used to form Ge NCs in the gate material.

2. Experiment

Tetrakis Ethyle Methyle Amino Hafnium (TEMAH) and O_3were utilized as the precursors of 20 nm HfO_2 deposition on (100) p-type Si substrates with the atomic layer deposition (ALD) method. The films were then implanted at room temperature with $^{74}Ge^+$ ions at 17 keV with a dose of 1×10^{16} cm^{-2} for the NFGM. The dose of ions and the kinetic energy of ions were determined using a TRIM(transport of ions in matter) simulation code. The Ge-embedded HfO_2 films in the MOS capacitors were annealed in O_2 and NH_3 gas ambient for 10 min at 800 °C, and Ti/Au electrodes were then formed using thermal evaporator system. The high frequency (1 MHz) capacitance-voltage (C-V) measurements were conducted using a HP 4285A LCR meter at room temperature.

3. Results and discussion

Several studies show that the annealing of the films in O_2 ambient will improve stoichiometry. However, as a result of this study, the annealing may not reduce the number of traps in the films causing leakage current. Figure 1 shows C-V curves obtained from the films annealed in O_2 ambient for 10 min at 800 °C. The counterclockwise C-V curves presentmemory windows related with the traps of HfO_2 film.

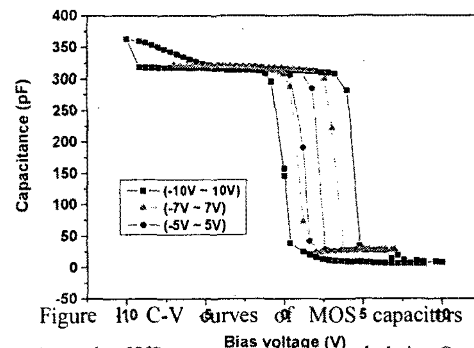

Figure 1. C-V curves of MOS capacitors without Ge NCs in HfO_2gate material annealed in O_2 ambient for 10 min at 800 °C

Recently, the physical characteristics associated with the nitridation of HfO_2-based high-k gate dielectrics have been actively investigated since nitridation can improve scalability, lower leakage, and higher breakdown fields even though the role of N diffused to HfO_2 material is not clearly clarified yet. C-V curves obtained from the HfO_2 films annealed in NH_3 ambient for 10 min at 800 °C don't represent memory effects (Fig. 2), in contrast to the C-V curves taken from the films annealed in O_2 ambient

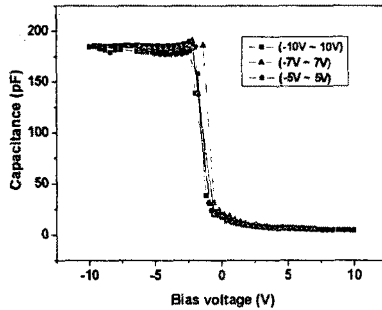

Figure 2. C-V curves of MOS capacitors without Ge NCs in HfO_2 gate material annealed in NH_3 ambient for 10 min at 800 °C

To form Ge NCs within the HfO_2 films after the Ge implantation into these films, annealing process is needed and in this study the same annealing condition as the above-mentioned HfO_2 film annealing was used. The implantation followed by annealing for forming Ge NCs from the implanted Ge ions in HfO_2 is a simpler fabrication of NFGM compared with NCs formation by other deposition methods. Also, the distribution can be controlled well adjusting implantation energy and ion dose.

Figure 3 shows the high frequency C-V curves obtained from the MOS capacitors with Ge NCs embedded in $HfO_2$and represents counterclockwise hysteresis with a 3.5 V memory window when the bias voltage was varied from −10 to 10 V, while there is little memory window in a curve taken from the MOS capacitors without Ge NCs. This result reveals that Ge NCs also act well as charge storage in HfO_2 films when the films are treated with NH_3 gas annealing.

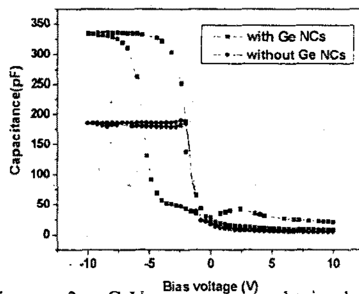

Figure 3. C-V curves obtained from the MOS capacitors with and without Ge nanocrystals annealed in NH_3 ambient for 10 min at 800 °C

4. Conclusion

MOS capacitors with HfO_2 gate material annealed in NH_3 ambient characteristics were compared between with and without Ge NCs and C-V results show that Ge NCs are related with memory effect for NFGM.

Acknowledgments

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